FINAL TECHNICAL REPORT

on

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ANALYTICAL THEORY FOR ARTIFICIAL SATELLITES

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FINAL REPORT

Advances in the technology to acquire data from satellites require more accuracy over longer intervals from orbit generators than it is feasible by numerical integration. As space software engineering is turning toward analytical solutions, the interface between a theory consisting of literal developments and a tracking system operating in real time must be worked out.

We recommend that the theory be used to generate <u>segmented</u> ephemerides: over a succession of finite intervals of time, the orbit is represented by a best approximation in the sense of Chebyshev expressed by means of Chebyshev polynomials. The advantages are:

1) a simple retrieval of the nominal orbit. Instead of tables of positions and velocities, one stores tables of coefficients for Chebyshev polynomials. The reduction in storage amounts to 60-70% at least. Such a compression decreases the number of I/O operations. It opens the possibility of storing an ephemeris for a few days in the on-board computer, or in microprocessors attached to the data collectors (for an on-site preliminary data reduction in order to decrease the cost of transmitting raw data to the master processing station).

2) faster generation of the nominal orbit. An interpolation, involving table look ups and divisions, is replaced by the evaluation of a Chebyshev series- which consists of a recursion over a stock of

3 words without divisions. (An operation rather simple to implement in a mini-computer and even a micro-processor).

We have constructed a general algorithm whereby, given a function and its first two derivatives over a finite interval, and an error bound, the minimum degree is found and the corfficicnts of the Chebyshev series are evaluated for which the discrepancy between the function and its best approximation is less than the given error bound.

The algorithm is based on Stiefel's exchange procedure to locate the reference points, and on Remez' characterization of the error curve to move the reference points toward the critical points.

The programs are written in PL/1:

1) the algorithm involves arrays of variable dimensions. The size of the arrays depends on the degree of the approximation which is determined from step to step by the algorithm. No language other than PL/1 and ALGOL allows dynamic assignment of dimensions for arrays.

2) PL/1 presents macro facilities that simplify the task of writing the programs in a structured manner.

A copy of the programs has been requested by the U.S. Naval Observatory.

The algorithm has been tested on several theories of classical astronomy:

1) the corrections in nutation;

2) the orbits of the inner planets (Earth, Mercury, Venus and Mars);

3) the Galilean satellites of Jupiter.

The results conform to the expectations: for instance, a full orbit of Venus (230 days) can be represented by 3 Chebyshev series of order 14 at the precision given by the American Ephemeris. In other words a table of Venus' orbit consisting of 3 columns, each one containing 230 entries, may be compressed into a table of 3x14 = 42 coefficients.

The results have been announced in (1) and (2). The algorithm has been presented in (3).

Information concerning the Galilean satellites will be submitted for publiuation.

Special care has been taken to document the programs by editing them and commenting them in place.

The author would be most willing to transfer the tape of programs to the Goddard Computer library. Beside the procedures to implement the algorithm, it contains the feeder programs by which the theories of Woolard for the mutation, of Newcomb for the inner planets and of Sampson-Sagnier for the Galilean satellites have been coded to generate positions, velocities and accelerations.

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